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Environmental Health Center
Cincinnati, Ohio

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The residantial sewage disposal system has taken an important place in American practice. In 1945 it was estimated that there were some four and one-half million individual systems, serving seventeen million persons in this country. With the increase in suburban development and with the increasing availability of electricity and transportation in rural areas, it is quite likely that the use of individual systems will continue to increase. In recent residential construction, it is estimated that 40 per cent of the homes being built with federal mortgage insurance are dependent upon individual systems for sewage disposal.

In an effort to improve our knowledge and understanding of these systems, the Environmental Health Center has been conducting a study program under the joint sponsorship of the Public Health Service and the Housing and Home Finance Agency. Two reports on these studies, entitled, "Studies on Household Sewage Disposal Systems," Part I and Part II, have been published and are available from the Environmental Health Center or from the U. S. Government Printing Office. The principal objective has been to learn the facts concerning behavior of home septic tanks and soil absorption facilities, under various loading and environmental circumstances, and to make available the factual information on which improved design and installation standards might be based.

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Before taking up the main investigations concerned with the soil absorption field and the tank proper, several special investigations have been made in which you might be interested.

Compounds

Questions on additives purported to "condition," "start" or even "clean" tanks come up frequently. Experiments at Cincinnati indicate that yeast has no merit as a "starter." These experiments are in agreement with those previously reported by Heukelekian.(1)

Some of the so-called "cleaners" which are being marketed contain caustic soda. Twenty-five pounds of caustic soda were added to a full-sized septic tank under laboratory observation. The effluent pH rose from a normal 7.3 to 12.4 and remained above 11.0 for about five days; digestion virtually ceased; and sludge swelled in volume. When soil cores were dosed with effluent containing caustic soda, at a pH of 10 or above, complete clogging occurred almost immediately. It is of interest to note that sodium hydroxide is used as a dispersing agent in soil textural analysis to destroy structure and to reduce the sample to its textural elements. When so dispersed, soil becomes an impermeable mass.

Ground Garbage

Changes in living habits bring up questions of their effect on the sewage disposal system. Current questions concern the effect of ground garbage, detergents, automatic washers, and brine waste from regeneration of home water softeners.

Ground garbage represents an additional solids load for which both the digestive and the storage capacity of the tank must be expanded. We

surveyed a number of systems in the field not long ago, including installations receiving ground garbage waste, and found that there is at least 50 per cent average increase in sludge plus scum accumulations, as compared with tanks not receiving ground garbage in that group. In this case it appeared that the greater part of the increase was in the scum. On the basis of what information there is, the 50 per cent increase in total tank capacity recommended by the Joint Committee on Rural Sanitation, for installations receiving ground garbage appears to be a reasonable precaution.

Laboratory studies lead us to believe that septic tanks receiving ground garbage will require larger absorption fields. Soil cores, ranging from silty clay to rather heavy clay, were dosed with effluent from a tank receiving ground garbage and sewage. Other cores were used as controls and dosed with normal effluent. Cores receiving the garbage-sewage effluent clogged more rapidly than those receiving the sewage effluent, both on a time, and solids-for-solids basis. The additional soil area required for the garbage effluent cores to equalize the clogging rates would be roughly 25 to 35 per cent. The recent examination of systems in the field indicates that there is more organic matter in soil samples from systems receiving ground garbage than from those not receiving garbage. On the basis of what is now known, I feel that an increase of 35 per cent in design absorption field size would be a reasonable precaution against failure due to inclusion of ground garbage.

Detergents

The effect of detergent use in the home has been studied in relation to the septic tank system. Digestion experiments conducted in bottles using a mixture of fresh sewage and ripe sludge revealed that a commercial anionic

detergent did not interfere with digestion when applied in concentrations of interest in home sewage disposal. Although the detergent used is of a class representing the bulk of production, "brands" vary in the composition of filler material as well as in the specific active agent.

In another series of bottle experiments seven common "brands" were tested at various concentrations. No detectable interference was caused by any of the detergents when applied in the concentration expected from average use. However, at concentrations which we can expect to be exceeded by five per cent of the families, several of the brands did cause interference with normal gas production.

In still another experiment, the commercial anionic detergent used in the first exploratory bottle experiment was added once each week, in the amount to be expected from a four load family wash, to a full sized experimental septic tank. During the twenty-seven weeks of the experiment there was no deterioration in quality of the effluent as measured by suspended solids removal. Sludge continued to accumulate at the same rate. Evidence indicated that there may have been some slight interference with anaerobic activity; but the interference, if any, did not reflect adversely on the performance of the tank. Grease content of the detergent tank effluent was about five ppm greater than that of a control tank. From a practical standpoint this small difference is doubtful. In conclusion, it might be said that there is no evidence that this detergent in the concentration to be expected from the normal family wash-day use would have any deleterious effect on the septic tank effluent.

Concerning the effect of another anionic detergent on soil absorption systems, studies in which detergent and soap respectively were added

to tank effluents, indicated no differences in clogging tendencies (other than those associated with differences in the amount of suspended solids). Similar studies using tap water suspensions of grease and soap, and grease and detergent did show differential clogging. There was immediate tendency for the soap-grease suspensions to cause greater clogging than the detergent-grease suspensions. Increasing quantities of grease in the soap suspensions caused slight increases in clogging, but the quantities of grease in the detergent suspension showed no apparent correlation with clogging. Another experiment was concerned with wash waters from a family wash. The housewife used soap one week and detergent the next. The wash waters were saved separately and applied continuously to laboratory soil cores for 90 days. No differences in clogging rates on either a time, or solids-for-solids basis was observed. However, there was evidence of some increased damage to soil structure under detergent dosage, which may cause increased clogging from a long time viewpoint.

Automatic Washers

A comparison of fifteen "conventional washer" against fifteen "Automatic washer" homes in Duval County Florida revealed that there was an increase in water use in the "automatic washer" homes. The increase was less than 50 gallons per bedroom per day in 95 per cent of the cases, but exceeded that figure in the remaining five per cent. The increase is probably due to change in home laundry habits with more frequent washes spread throughout the week.

A study of data from field inspections was made to determine the effect of increased per capita water use on the accumulation of solids. The range of water use covered by the sample was from 8 to 149 g/c/d,

which is large enough to encompass the expected increase due to automatic washers. The examination showed that there is no correlation between water use and solids retention in the range covered by the sample. This might be evidence that increased water use would have no adverse effect on tank performance. However, a sizeable increase in the liquid volume of waste will require a proportionate increase in the soil absorption area.

Brine Wastes

Many localities have become interested in the effects of discharging water softener regeneration waste to the septic tank system. As you know, these wastes contain a high concentration of the mixed salts of sodium, calcium and magnesium. Early bottle tests indicated that a 1.2 per cent solution of mixed salts inhibited digestion; and that this effect was reduced by mixing and flushing. A 2.4 per cent solution settled to the bottom of a full-sized tank and failed to dilute in the bottom layers even under the influence of periodic sewage feeds.

Another experiment has been completed in which, in addition to the regular feeds of raw sewage, mixed salts were introduced into a full-sized tank once each week in a manner designed to simulate the regeneration of a water softener. Chloride concentrations built up to a high ranging from 1.0 to 1.2 per cent near the bottom of the tank during cold weather; however, for all practical purposes, the tank purged itself of salt with the advent of warm weather. In spite of high salt concentrations in the sludge layer, digestion seemed to proceed well at all times during this experiment. Further investigation revealed that sludge in the tank had become acclimated to a salt environment. This behavior might not develop in a tank having little or no sludge accumulation when brine discharges start. Therefore,

caution should be exercised in applying these results to a new installation or to one which has been cleaned and returned to service without seed sludge.

Dosage of soil cores with effluent from the tank receiving sewage and brine waste indicated no short time damage to percolation rates as compared with normal effluent; but there was some damage to soil structure, which may be important from a long time viewpoint.

Soil Studies

Coming now to the soil studies, I should like to take a moment to emphasize the importance of this part of the system. The conventional disposal unit depends on the soil for final treatment, and ultimate disposal of the waste. In this light, it is of interest to consider the tremendous amounts of liquid being applied to an absorption system as compared to what soils normally absorb from rainfall or from irrigation. Average rainfall in this country as a general rule will vary from 30 to 50 inches a year depending on locality. Allowing for evaporation and runoff, the soil absorbs some 20 to 40 inches of this moisture. In irrigation, the maximum amount of water applied annually is about 100 inches. However, in current home absorption field design practices the soil is required to absorb some 200 to 1,100 inches annually, with extreme cases found in the field amounting to over 2,000 inches annually. It is evident then that the quantity of liquid imposed on the soil is in itself a major factor, to which is added the complicating influence of sewage constituents.

A major problem in connection with the soil absorption system is to determine the absorption area required for any specific system. The answer to this problem will depend on a number of factors such as: the quantity and composition of the waste to be disposed of: the climate of

the area; the absorption characteristics of the soil; and the clogging characteristics of the effluent. Probably the most important single factor is the ability of the soil to absorb water. Therefore, one of the principal objectives in the study is to devise a method whereby the water absorption characteristics of a soil may be measured.

This is a problem which concerns many others besides those interested in sewage disposal. Agricultural workers have been interested and have worked on the problem for years, particularly in relation to irrigation and to soil drainage. The problem is still a long way from satisfactory solution. However, there have been methods and aids developed which are of great help. For many areas literature is available from which considerable background information can be obtained. Probably the most valuable sources of information are the soil survey reports. These reports generally cover an area about the size of a county. They consist of a detailed soils map and an accompanying description of each soil type. Unfortunately, actual percolation rate values are seldom given, but at least the general suitability of a soil for absorption fields may be interpreted from such reports. This information may be of particular value in determining the suitability of a location for a large housing development.

Several indications of the water absorption characteristics of a soil may be obtained through close visual inspection. The value of such an inspection depends on being able to recognize pertinent details and clues, but this does not necessarily require a trained soils man. Anyone with a minimum amount of training can learn to recognize significant clues. The main features to look for are texture, structure, and color.

Texture

Texture, or the relative proportion of sand, silt, and clay in the soil, is probably the most common clue. The size of the particles govern the size of the pores which in turn directly govern the amount and the rate of water absorption. The larger the particles the larger are the pores and the faster is the rate. Texture can be judged best by the feel of the soil when it is wetted and rubbed between the fingers. The lighter or sandier soils have a gritty feel; silt types have a floury feel; the heavier clay soils have a slick feel. However, the use of texture as an indication of absorption qualities has its limitations. It is mostly reliable in the sandy range. In the heavier types, which contain appreciable amounts of silt or clay, we must look for additional clues, such as structure.

Structure

Structure may be described as the tendency for the individual textural particles, particularly the clay particles, to aggregate or group together and form secondary particles of larger size which are more or less stable to wetting and to physical breakdown. Such secondary particles, rather than the textural particles, then tend to govern the size and distribution of pores and in turn the absorption properties. Structure can be recognized by the manner in which a clod or lump breaks apart. If a soil has a developed structure, a lump will break with very little force along well defined cleavage planes, into uniform sized and shaped units. On the other hand, if a soil has no structure, a lump will require considerable force to break it apart, and when it breaks it will do so along irregular surfaces. Occurence of structure is a good indication that soil will have more favorable absorption characteristics than a similar type soil (clay, silt, loam, etc.) with no structure.

Color

The final important clue is color. Relatively bright uniform reddish-brown to yellow colors throughout a profile indicate that there have been favorable oxidation conditions with relatively free alternate movement of water and air in the soil. Such conditions favor desirable moisture absorption properties. At the other extreme, are soils which are light gray throughout the top soil; and are dull, drab, and mottled in the subsoil. Such conditions indicate lack of oxidation and a very restricted movement of air and water. Such soils are quite likely to have unfavorable moisture absorption properties.

Again, as with the soil survey reports, visual inspection will aid in appraising the general suitability of soils for absorption fields, but for design data it will still be necessary to turn to some direct method of measuring water absorption rates.

Percolation Tests

In the sewage disposal field, the work of Henry Ryon(2) in the 1920's has provided a useful tool for estimating soil moisture absorption rates. Ryon developed and put into use a percolation test by which he measured the rate that a soil would absorb clear water. Then from a study of systems which had failed after some twenty years of operation, he also developed an empirical relationship between this clear water rate and the rate that the soil could be expected to absorb septic tank effluent. It is this test and empirical relationship, or slight modifications thereof, upon which most of the tests and design specifications being used today are patterned. In this connection, from a review of specifications of control agencies, it appears that testing of water absorption capacity of the soil

by a percolation test, and design of the system size on that basis, is not applied as widely as it should be.

The Ryon type test as generally run involves digging a one-foot square hole to the anticipated depth of trench bottom, filling the hole with at least six inches of water and observing the time required for the water to seep away. Some modifications require that the test be repeated if the soil is dry, and some require that the rate of fall of the last inch of water be considered the percolation rate. In any event, specifications in general are open to individual interpretations, and there appears to be a need for improvement and standardization of the test.

Modifications of the Ryon Test

One of our major efforts in the soils studies at Cincinnati is to examine the Ryon type test in a wide variety of soils. As a result of studies completed thus far, the following modifications are suggested: (1) substitute a four-inch auger hole for the laboriously dug twelve-inch square hole; (2) saturate the soil more completely by a standard procedure; and (3) use the minimum observed percolation rate for design instead of the average or some initial rate.

The first modification, the use of a four-inch auger hole, is justified since no significant differences were observed in the rates measured in the different sized holes in the same soils. In fact, there was as much variation between the rates measured in replicate holes of the same size as there was between the rates obtained from different sized holes. At first thought, the use of a small auger hole may appear to be a minor change, but it is a potentially important one from the viewpoint of the person who makes the test. The auger hole is easy to prepare. Furthermore,

for each filling, a four-inch auger hole takes approximately one-twelfth the volume of water required for a twelve-inch square hole. This saving is an important consideration in cases where water must be transported to the site.

The saving in time, labor, and water should be invested in making replicate tests. Due to soil variability, a single test is often useless in estimating the absorption characteristics of an area even as small as 100 foot square. Six tests spaced uniformly over such an area are needed to obtain a reliable estimate.

Soil Saturation

The second suggested modification, to saturate the soil more completely, is necessary in order to obtain consistent results regardless of prior moisture conditions and regardless of the time of year that the test is made. Such saturation is desirable also in order to approximate soil conditions that will prevail in the absorption field. Anyone who has made a percolation test is familiar with the decrease in percolation that takes place during a test. The magnitude of this decrease and the length of time over which the decrease continues depends upon the type of soil, and prior moisture conditions. The decrease will be more pronounced if the test is started in a dry soil and is likely to be more pronounced and will take place over a longer period of time in clay type soils.

In order to judge its practical importance, a detailed study of this percolation rate decrease in several soil types has been made. Two-day percolation tests were conducted at a number of sites. On the first day, a test was made in the conventional Ryon manner. After which, percolation test holes were filled with water and soaked over-night. On the second day the test was repeated.

The results of one such series of tests in a Rossmoyne soil exemplifies the importance of complete saturation. The site, if considered on the basis of the Ryon run, had a percolation rate of 44 minutes per inch and would be considered acceptable for an absorption field. Approximately 200 square feet of absorption area per bedroom would be required as judged by the Joint Committee on Rural Sanitation tables. However, on the second day the percolation rate was 66 minutes per inch, which would make the site unacceptable.

The latter case agrees with actual performance in this soil. Of several systems inspected in the vicinity not one was considered satisfactory. One system, about five years old, was inspected in detail. This system contained approximately 300 square feet of absorption area and received toilet wastes only from one adult and two children. It was found to be completely flooded and had serious surface seepage. The inspection was made during August when conditions in general should have been most favorable for successful operation.

As a rule, the rates obtained using the improved version of the percolation test will be slower than those obtained by tests in general use at this time. For this reason the validity of applying the slower rates to present "Rate vs absorption area" tables is questionable. At this time all that can be said is that any error involved is on the safe side. Thus, results of the modified test may be safely used with present tables which have been derived from the Ryon data.

However, it is desirable to develop new and additional percolation rate-allowable sewage loading rate tables for a number of reasons. First, of course, the relationship may be different when a more rigidly controlled

test is used for measuring percolation rates. Secondly, the empirical relationship given by Ryon was developed with a limited amount of data under limited soil and climatic conditions occurring in New York. An entirely different relationship may exist under midwest soil conditions, for example, where the soils tend to be deeper. Thirdly, the relationship may be influenced by sewage characteristics. Obviously, the Ryon relationship was developed under sewage characteristics prevailing about 1920. With increasing use of home garbage grinders, use of automatic washers, use of detergents to replace soaps, and changed living habits in general; the composition of sewage is somewhat different today.

We are at present conducting a cooperative field study with a number of local public health engineers and sanitarians over the country aimed at developing the empirical relationship between the modified test and actual performance.

Clogging Characteristics of Effluent

Certain properties of septic tank effluent may be major factors in soil clogging, and may, therefore, influence absorption area requirements. From agricultural experience we can consider soil clogging in three categories: (1) physical, (2) biological and (3) chemical. Septic tank effluent is a physical, biological, and chemical complex and may contribute towards all types of clogging.

The physical type of clogging is obvious; it may result from the physical plugging of the soil pores by the solid particles in the effluent.

Biological clogging, which is a common problem in agricultural water spreading work, may result from plugging of pores by biological bodies and

by-products, or it may result from the biologic activity destroying or altering the soil structure. Actually, it appears that biological activity does not cause soil clogging under effluent loading; but instead it tends to reduce clogging that might be caused by other factors. Laboratory soil cores packed with a variety of soils and dosed with effluent over a three-month period clogged in proportion to the amount of suspended solids in the effluent. After a few weeks of dosing, biological activity appeared to take effect, and the rate of clogging was reduced. Also, studies involving the application of normal and of disinfected effluent to soil cores resulted in a more rapid rate of clogging by the disinfected effluent, confirming the observation that biological activity tended to reduce the rate of clogging. Apparently digestion of solid materials in the effluent takes place in the soil and results in a net decrease in the clogging effect of the effluent.

The third type of clogging, chemical clogging, is a common agricultural problem in the western part of our country, particularly where irrigation is practiced. A classic example is the "black alkali" soils that develop in some areas as a result of irrigating with water high in sodium content. For this reason water quality has to be carefully controlled. It is generally considered that waters containing 50 per cent or more of the total cations (sodium, calcium, magnesium, and potassium) as sodium are potentially harmful to the water absorption characteristics of soil. Even on sandy soils, after prolonged use, waters containing more than 85 per cent of the total cations as Na are likely to make soils impermeable.

In our experimental study of the effluent sodium clogging influence, the relative amount of sodium to calcium was modified by adding gypsum to

the effluent. It was found from core dosing studies that soils having a well-developed structure tended to maintain the structure and clog less under the calcium fortified effluent dosage than with normal effluent dosage. In single grained soils, with no apparent structure, there was no difference in the rate of clogging between the fortified and normal effluent dosed cores.

As was previously mentioned, some proprietary septic tank "cleaning" compounds contain caustic soda. Soil cores dosed with effluents to which caustic soda had been added, in concentrations well below those expected from a typical "cleaning" dose, caused immediate clogging. Similar, although less dramatic, results were demonstrated using potassium hydroxide.

Previous mention has also been made of the effect of ground garbage, detergents, and softener wastes on soil clogging.

Tank Studies

Turning now to the study of tanks and their related appurtenances, full scale septic tanks were dosed with fresh sewage from a combined sewer serving a nearby residential district. Raw sewage was pumped to an elevated conical shaped dosing tank equipped with a stirrer. Approximately every two hours all tanks were dosed in rotation with an equal amount of sewage. Eight daily feeds were made, and the quantity of each feed was varied to conform to a pattern of metered water use. The rate of influent was manually regulated at 10 gallons per minute. All effluent was collected in individual receivers after each feed, and samples were taken. Routine solids, temperature, and pH determinations were made on both the effluent and the raw sewage. Special determinations including B.O.D., dissolved

oxygen, sulfides, grease, gas analysis, and bacteriological examinations were made when necessary.

Shape

In the first phase of the study, 18 full size septic tanks were operated under parallel conditions for periods up to a year. Included were five single-compartment tanks of approximately 500 gallons capacity but of different shapes. Vertical and horizontal circular, rectangular, and oval-shaped tanks were represented. Under identical circumstances the suspended solids removals for all five tanks for the entire year ranged between 59 and 65 per cent. In other words, for the same capacity, variation in shape of the single-compartment tank had no appreciable effect on efficiency.

Capacity

Laboratory studies have demonstrated the importance of ample tank capacity. A large 2,060-gallon single-compartment tank removed 80 per cent of the suspended solids compared with the 60 per cent mentioned above for 500-gallon single-compartment tanks. The comparison was made during a year of operation over a range of sludge accumulations. This difference in performance is more evident when it is considered from the viewpoint of solids in the effluent. Assume, for ease of calculation, a sewage with 100 ppm of suspended solids. Approximately 40 ppm of those solids would pass through a single compartment tank of 500 gallons capacity while only 20 ppm would be found in the effluent from the larger tank. The larger tank would, therefore, cut the solids load going to the soil by one-half. Tanks having capacities of 289, 246 and 123 gallons respectively

quickly reached sludge storage capacity, with accompanying drop in suspended solids removals.

The provision of liberal capacity is not only important from the technical standpoint but it pays off economically in the long run. The cost of cleaning home septic tanks ranges from $15.00 to $300.00 in this country. A short time ago the cost of a 500-gallon concrete tank in a southern locality was $55.00 and that of a 750-gallon tank $65.00. This represents 50 per cent additional capacity for $10.00 additional cost. If cost of installation is included, the 50 per cent additional capacity could probably be purchased for 25 to 30 per cent additional cost. The point is, that the 50 per cent additional capacity would stretch the period between cleanings to roughly two times the original. In view of the charge made for cleaning, an economic advantage is apparent.

Compartmentation

Keeping the 59 to 65 per cent suspended solids removals of the five single-compartment tanks in mind, I want to discuss the performance of two multi-compartment tanks which were operated at the same time, under identical loading and sludge addition circumstances. These were a 550-gallon two-compartment, 36-inch diameter, vertical circular; and a 670-gallon four-compartment, 24-inch diameter, vertical circular tank. These tanks performed at 78 and 84 per cent suspended solids removals for the year, roughly 20 points above that of the single chamber tanks.

More recently, experimental investigations of the effect of number and proportions of compartments have been undertaken. The liquid capacity of each tank was 500 gallons. A two equal-compartment arrangement showed

advantage over a single compartment tank. A three equal-compartment arrangement, however, did not show advantage over the single-compartment tank. Placing two-thirds of total capacity in the first compartment resulted in performance about the same as that of the two equal-compartment control tank. With reversal of the arrangement, that is, one-third of total capacity in the first compartment, performance fell off below that of the control.

There is, therefore, advantage in performance to be gained, either by large increase in capacity or by multi-compartmentation. At this point in the multi-compartmentation studies it appears that a two-compartment arrangement, either with equal compartments, or with about two-thirds of total capacity in the first compartment, shows promise.

It should not be inferred from this that the well-designed single-compartment tank of ample capacity will not give good performance. In well drained soils an absorption system following such a tank should have a reasonably long life. However, for the less open soils the advantage of the greater suspended solids removal and the better stability of the larger single tank, or of the multi-compartment tank, should be considered.

Appurtenances

Several exploratory trials of tank inlet, outlet and intercompartment flow appurtenances have been made using a dye tracer. Tank detention time and flow pattern were used as "yardsticks" for comparison. An unbaffled plain inlet, a baffled inlet and a tee fitting inlet were all essentially equal in effect on detention time, but the tee provided a slightly better flow pattern than the other two. In these experiments a four-inch pipe entered each tank with its invert three inches above the liquid level. In an experiment on outlets, a tee was compared experimentally

with a tank-width baffled weir. There was no difference in effect on suspended solids removal among them. Concerning inter-compartment connectors, experiments using the dye-detention-flow pattern yardsticks indicated that 4-inch tee and bend connectors resulted in longer detention time and better flow pattern than a four-inch high tank-width slot submerged 12 inches to top of slot. Replacement of the slot by a single four-inch diameter hole, also at 12 inches submergence, increased the detention time and improved the flow pattern but was not quite as good as the pipe fitting arrangement in this respect. For practical purposes either the pipe fitting or hole arrangement should perform creditably.

Depth

There have been questions on the effect of tank liquid depth on performance, arising where prefabricated tanks of less than the commonly recommended four foot minimum have been offered, or where difficult installation circumstances may make a shallow tank installation more desirable. As the studies on tank shapes were made at roughly four feet water depth, another experiment was conducted to investigate the depth effect. Four single-compartment tanks, all of 500 gallons capacity but varying from 28½ inches to 64 inches in liquid depth, were used for the purpose. Early trends at low sludge levels indicated no difference in suspended solids removals among the four.

As the experiment progressed, under the influence of periodic sludge additions, the individual tanks reached their sludge storage capacity and went into a state of failure. The order in which the tanks failed was entirely independent of the depth factor. Judged by the ability to store sludge, the rank from best to poorest was the 28½-inch, followed by the 64-inch, next the 36-inch, and last the tank 48 inches deep.

These results indicate that it is possible to reduce liquid depth below the usual four-foot requirement with some improvement in performance.

Clear Space

Early evidence contained in data from field inspections led us to believe that there might be a limiting level below the bottom of the outlet tee above which sludge could accumulate only at the expense of performance. This minimum distance between top of sludge and bottom of outlet has been termed "clear space." First evidence favored the theory of a constant clear space at approximately one-foot regardless of depth or capacity. However, the results of the depth study refuted this theory.

Consequently, an analysis of sludge accumulation behavior in all ten of the 500-gallon straight, vertical wall septic tanks operated in the laboratory was made. The clear space which had developed just before failure was determined. A strong correlation between this minimum clear space and surface area of the tank was found. That relationship can be expressed by the equation:

$$\text{Clear Space} = 2.85 - 0.08A$$

where clear space is in feet and surface area is in square feet.

The equation given is not the regression line for the sample; rather, it represents the upper 90 per cent confidence limit for the true regression line.

Field Investigations

Field investigations supplement the laboratory experiments, and also provide valuable information which cannot be obtained in the laboratory. For instance, the waste to be disposed of results from circumstances in a

particular home. It is subject to variations in quantity and composition depending on family size, living habits, and other factors peculiar to that home; and is not a composite of the wastes from many homes, such as we would have in municipal sewage. The water consumption in a group of homes which we studied averaged 39 gallons per person per day in winter and 49 in summer. In the same group the variation was from 8 to 150 gallons per person per day in winter and 8 to 226 in summer. The character of residential waste is influenced by individual practices in the use of soaps, detergents, garbage grinders, washing machines, and sometimes, water softening units.

A change in occupancy is another factor which introduces variation. Therefore, for design purposes the size of the home is considered a better measure of load potentiality than the number of initial occupants. One exception to this rule is the case where a home is constructed initially to serve a large number of occupants. It is of interest that two-bedroom homes tend to have larger person-per-bedroom occupancy than three-bedroom homes, and the three- larger than the four-bedroom home. Similarly, larger water consumption per-person develops in the small home, and decreases toward the larger homes. It follows from this that unit loadings for the small home would be larger than those of the larger home. It is necessary to take variability into account; because although averages may be useful in reflecting trends, final application must result in designs which will serve most, if not all, of the individual cases.

Sludge and Scum Accumulation

Capacity

During the period, February, 1947 to July, 1948, 300 single household septic tanks in normal operation, located in nine areas over the country,

were examined by two-man, engineer-laborer teams. Sludge and scum accumulations were measured and the family history and living habits at each installation were taken. Using unit accumulation of sludge and scum as the basis, a comparison was made to determine how change in capacity would effect the performance of tanks. It was found that in tanks in the 125 to 175 gallon per capita liquid capacity group, unit accumulations approximated the average accumulation for all tanks of all capacities. Tanks with per capita capacity smaller than 125 to 175 gallons accumulated less sludge and scum; while larger per capita capacity tanks tended to accumulate more solids in the same period of time. This study of sludge and scum accumulation again demonstrates the importance of adequate capacity. The significance of capacity is driven home when we consider that solids which are not retained in the tank must pass on to the distribution field where irreparable damage to soil can occur.

Ratio of Submerged Scum

Other information on the accumulation of sludge and scum has been developed which is useful for the rational design of a septic tank. Scum floats with approximately one-quarter of its total thickness above water line. An extensive analysis of the data, using several methods independent of each other, leads to the conclusion that twenty-seven per cent is a reasonable proportion for submerged scum to total submerged accumulation.

Rate of Accumulation

Rates of scum and sludge accumulation which experience shows will be exceeded by only one case out of twenty are:

For Scum $Y = 3.2 + 1.4\ (t)$

For Sludge $Y = 10.4 + 2.2\ (t)$

Where: Y = cubic feet per bedroom

and t = years of operation

These rates are roughly two to three times the average rates of accumulation.

Knowing the tank depth which must be allotted for minimum clear space, the rate at which solids will accumulate, and the proportion of scum solids which will accumulate below the liquid line, it is possible to permit penetration of the outlet device to provide for a balance between scum and sludge accumulation. Maximum storage capacity, and hence the longest cleaning interval will result from this balance in design.

Cleaning Interval

While we are on the subject of cleaning intervals, it might be well to discuss the matter more thoroughly. To the best of my knowledge, there is no way to which the physical removal of accumulated solids from a septic tank can be avoided if efficient operation is to be maintained, and if the all-important water absorption characteristics of the soil are to be protected. I am inclined to feel, however, that the setting of some blanket cleaning period, whether it be three or five or some other number of years, does not answer this problem. As you may have gathered from my remark concerning the equations for accumulation, there is considerable variation in the rate at which individual installations will accumulate sludge and scum. In order to safeguard the high-accumulation installations, a short cleaning period would severely penalize those systems which could

safely run several times as long without cleaning. An economical solution would depend on periodic inspections of individual tanks by the home owner or others so that cleaning could be accomplished as necessary. We have attempted to develop some means whereby the accumulation of solids might be gaged, using a simple home-made device. For practical purposes the sludge level can be found by lowering a long stick to which a piece of bath towelling is attached, into the tank and leaving it in contact with the contents for several moments. A hinged flap on the end of a stick, which may be pushed through the scum and raised in an open position, will serve as a simple home-made scum gaging device.

Conclusion

Before closing, there are a number of observations concerning design and maintenance which I should like to make.

Concerning unit design problems, one of the obstacles to good septic tank performance has been the tendency to skimp on capacity. This is false economy and an invitation to trouble. Scum retention tees or baffles are important appurtenances. Sometimes they have been poorly designed, or poorly installed so that they drop off. Surprising as it may seem, tanks are sometimes designed and installed without means of access. Percolation tests for the design of soil absorption systems are not as widely applied as they should be. Except in very porous sandy soils or in very tight clays, a decision on whether the location is suitable for the absorption type system, and if so, how much absorption area is needed, based on anything short of percolation tests, leads to failure. Even the trained soil scientist must use percolation tests to determine soil

water absorption capacity with reasonable accuracy, except for the extremes above mentioned.

The effectiveness of good design may be lost through careless installation. A few difficulties might be cited. Exposure of open trenches in freezing weather during construction has resulted in system freeze-ups during initial operation. Carelessly laid tile lines result in poor distribution. Inlets have clogged because the sewer had been pushed into the tank against the baffle, or because the sewer had been cut off carelessly, leaving a ragged edge to snag material. Baffles have been broken by ramming the sewer into the tank. There are instances where tanks have been installed backwards.

One of the major sources of trouble is neglect of maintenance. Some cleaners claim that in over 50 per cent of their cleaning jobs, they are called in after sludge accumulations have exceeded tank storage capacity, and spillovers have clogged the absorption system. This is not necessarily any deliberate neglect by the home owner. It has been our experience during field inspections that the householder is usually uninformed as to the location of his facilities, what they are, and what he should do to maintain them. We found no lack of householder interest, however, and in our opinion, many difficulties will disappear when the householder is given the necessary information. There is a leaflet, "Septic Tank Care," prepared by the Division of Sanitation of the Public Health Service, available from that the office, or in quantity, from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., which should be helpful. The leaflet describes briefly the system and functions, provides guidance on maintenance, and space for a layout sketch of the system and record of

servicing. The amount of attention required in these systems is very little actually, but too often the householder is left unaware of any responsibilities until sewage backs up and an expensive reinstallation is required.

In closing, there are two thoughts which in my opinion cannot receive too much emphasis. The first is that the septic tank is not a disposal system of itself, but is an important unit of a process in which the objective is the disposal of waste liquid into the ground. Soil, for waste disposal purposes, is a sensitive medium, not only sensitive to the heavy liquid loadings we place on it, but susceptible, also, to damage from abnormal changes in the waste being applied to it. We should keep this in mind, not only in considering septic tank design and operating factors, but also in connection with servicing procedures. The second thought is that while the development of factual information is of fundamental importance, it will fall short of its purpose if it is not applied to the design, installation, operation and servicing of each individual installation.

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